Nov. 11, 1947. C. G. SMITH 2,430,482

GASEOUS ELECTRIC LAMP

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FIG. 1.

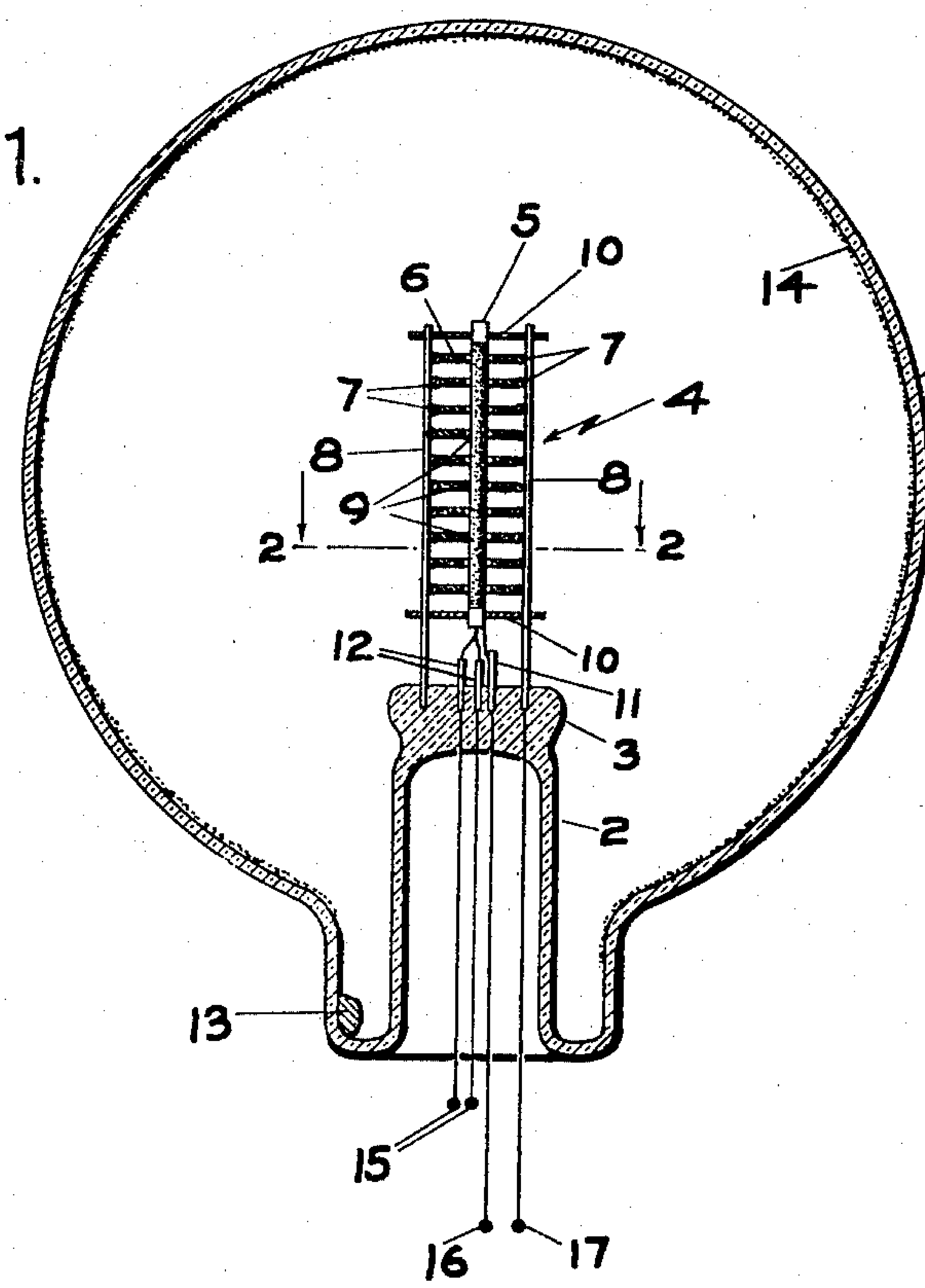

FIG. 2

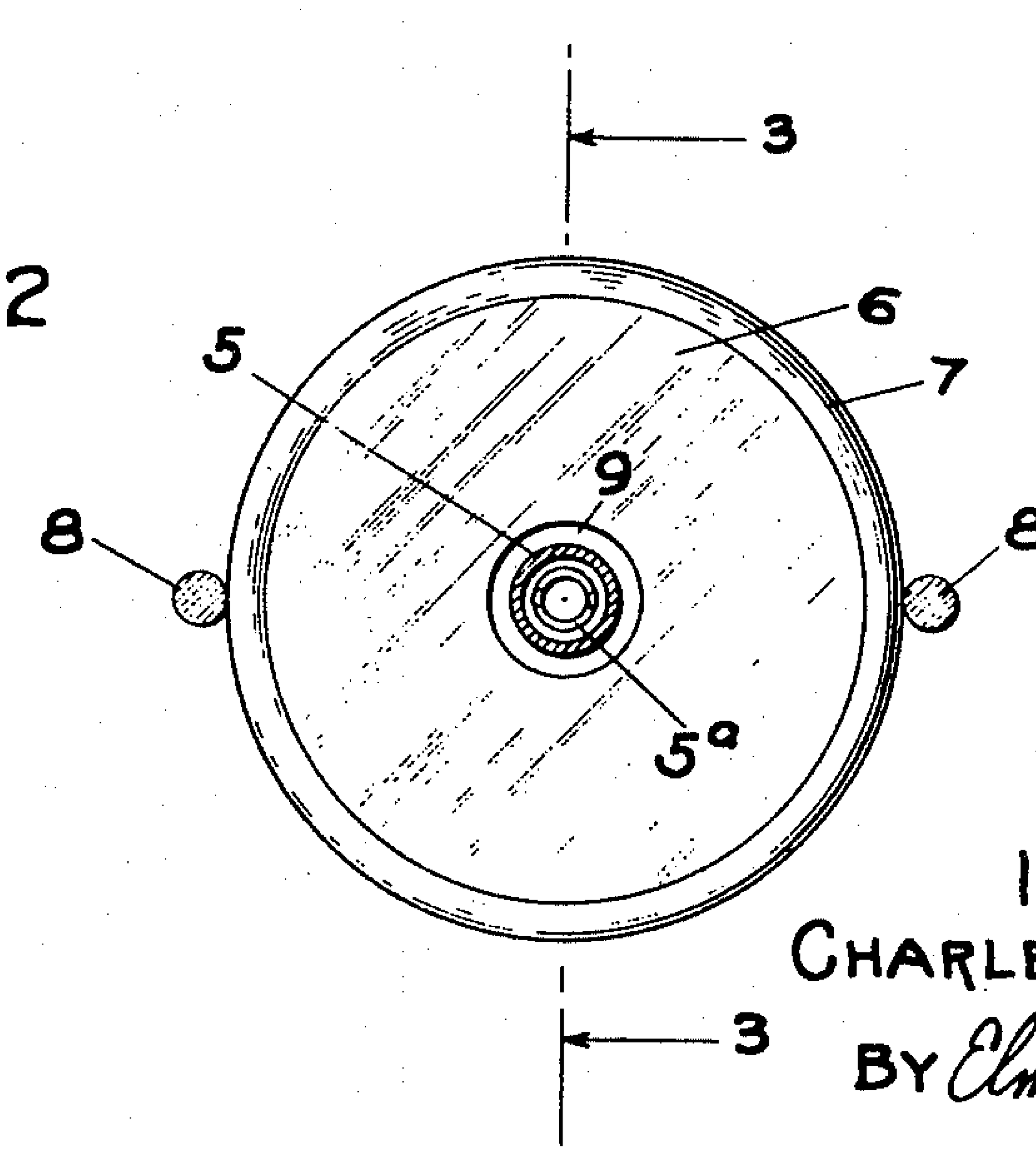

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FIG. 3.

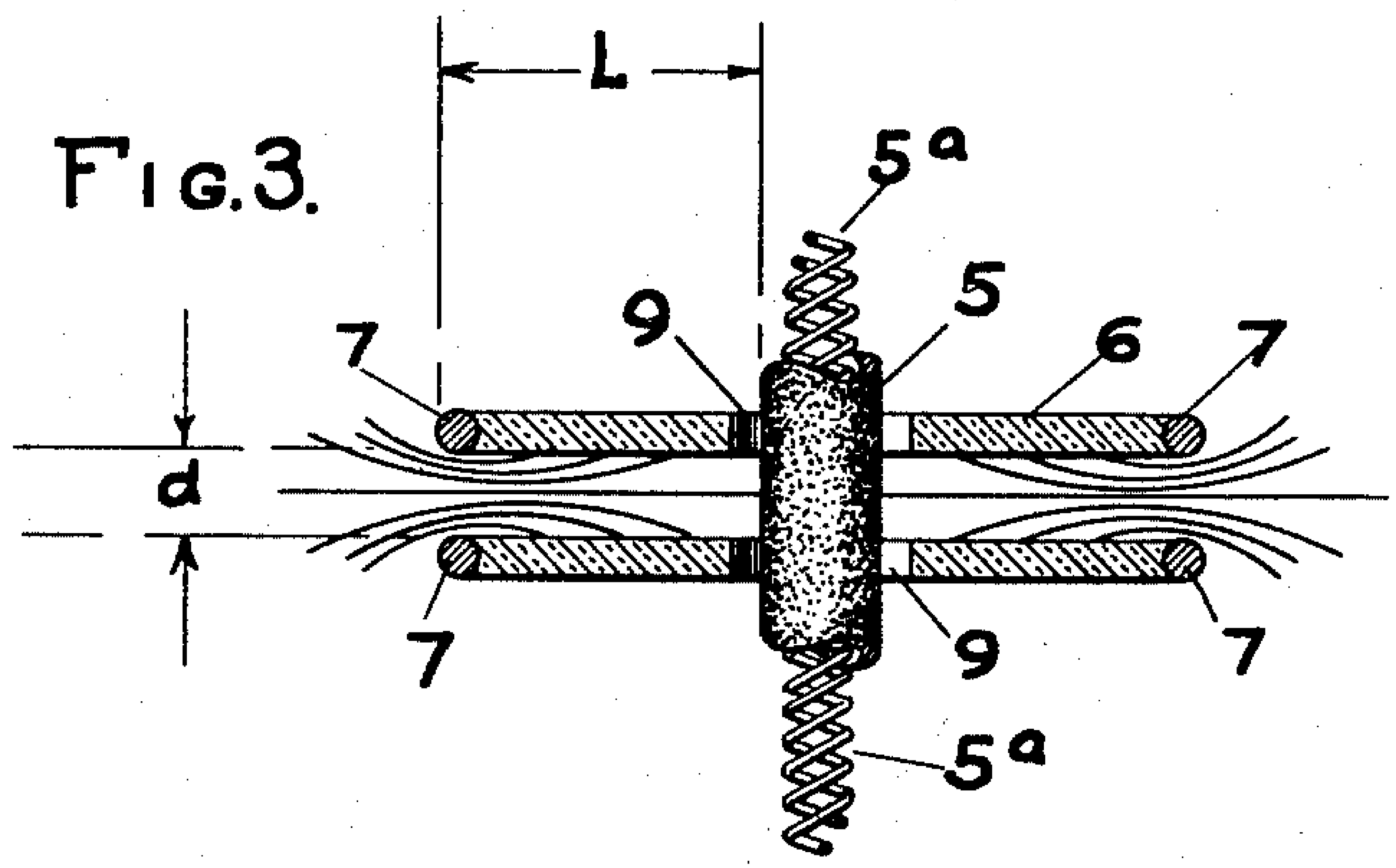


FIG. 4.

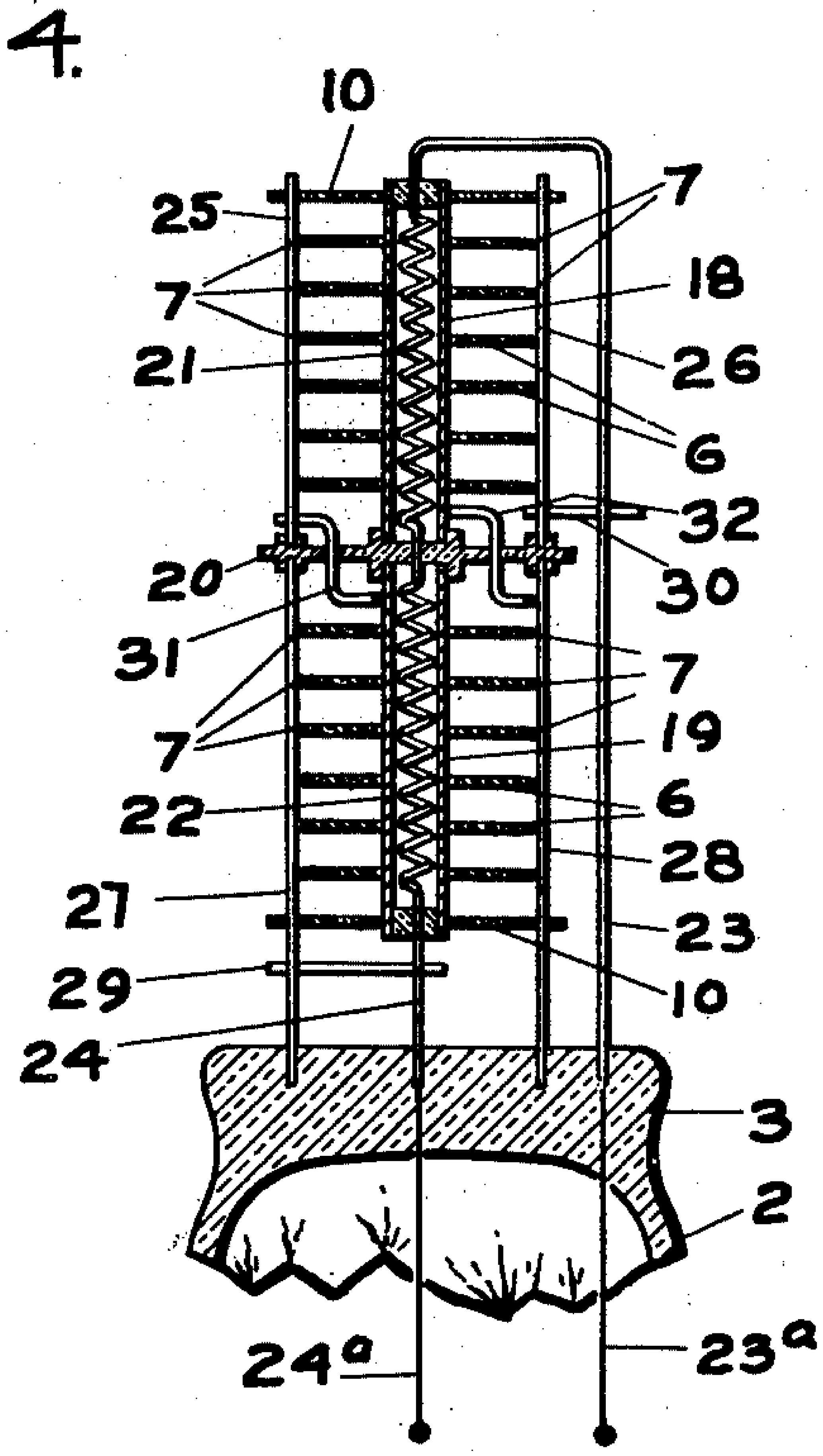
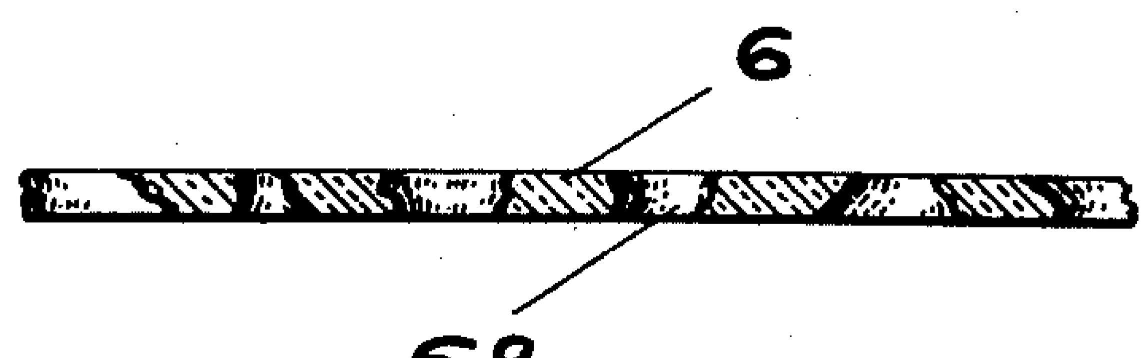


FIG. 5.



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2,430,482

GASEOUS ELECTRIC LAMP

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Application February 12, 1942, Serial No. 430,581

8 Claims. (Cl. 176—122)

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This invention relates to a gaseous electric lamp wherein a stream of electrons is projected into a region containing one or more gases at reduced pressure.

An object of this invention is to produce a lamp of the above type in which, however, the electron gun comprises one or more electron beam-projecting passages formed by insulating or relatively low conductivity wall members.

Another object is to produce such a lamp which has a stable electrical characteristic wherein an increased current is accompanied by an increase in the voltage applied across said lamp.

Another object is to produce such a lamp in which the starting voltage is substantially less than the peak voltage applied thereto.

A further object is to produce such a lamp which will operate on the electric lines now in common use for illumination without the necessity of using an auxiliary energy-consuming apparatus.

The foregoing and other objects of this invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is a diagrammatic cross-sectional view of a lamp embodying my invention;

Fig. 2 is an enlarged cross-sectional view through the electrode assembly, taken along line 2—2 of Fig. 1;

Fig. 3 is a fragmentary section taken along line 3—3 of Fig. 2;

Fig. 4 is a diagrammatic vertical section of an electrode assembly adapted for use on alternating current and constituting another embodiment of my invention; and

Fig. 5 is a fragmentary cross-section taken through a special type of insulating material which may be used in any of the lamp structures illustrated.

The lamp illustrated in Figs. 1, 2 and 3 consists of an envelope 1 of some suitable transparent material, such as glass, at the lower end of which is formed a reentrant stem 2 carrying a press 3 at its inner end. The press 3 supports an electrode assembly 4 including a cathode 5, preferably of the indirectly-heated type, consisting of a metal sleeve coated with alkaline earth oxides and surrounding the filamentary heater 5a, as shown in Fig. 2. The cathode 5 is surrounded by a plurality of flat insulating washers 6. These washers 6 preferably have certain characteristics which will be described in detail below, whereby the lamp is given the desired operating char-

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acteristics. Each washer 6 has mounted on the outer periphery thereof a conducting wire ring 7. These rings are preferably intimately in contact with the outer edges of said washers 6. The rings 7 are electrically interconnected by conducting support rods 8 running longitudinally of the electrode assembly and sealed at the lower ends in the press 3. The rings 7, thus electrically interconnected, collectively at as the anode of the electrode assembly. Each washer 6 is provided with a central opening 9. These openings are aligned so as to provide a central opening in which the cathode 5 is located. The ends of the electrode assembly are preferably closed by a pair of insulating spacers 10—10. The press 3 has sealed therein a lead-in conductor 11 electrically connected to the cathode 5 and serving to provide an external electrical connection thereto. The ends of the cathode heater are connected to a pair of lead-in conductors 12—12 likewise sealed in the press 3.

The envelope 1 has introduced therein a small quantity of vaporizable material 13, such as mercury, which supplies a vapor, such as mercury vapor, at a pressure of the order of ten microns or less during operation, and constituting an ionizable atmosphere within said envelope. In addition to the vapor, a small amount of a gas, such as helium, at a pressure of the order of ten times that of the vapor is preferably contained within the envelope 1. The pressure of the helium may lie, for example, within the range of five to one hundred microns.

The lamp, as described above, is adapted to energize the gaseous atmosphere so as to produce light radiations which, in the case of the materials specified above, lie mainly in the ultraviolet region. By the term "light radiations" in the specification and claims herein, I include radiations which lie in the visible, infra-red and ultraviolet spectra. The ultra-violet radiations thus generated may be converted into visible light radiations by means of a fluorescent material 14 coated on the interior walls of the envelope 1. The circuit with which the lamp described may be utilized is extremely simple. Thus the lead-in conductors 12 may be connected to the pair of terminals 15 which are adapted to be directly connected to a suitable source of heating current. The lead-in conductors 11 and 8 are adapted to be connected to a pair of terminals 16 and 17 which may be connected directly to a suitable source of current; for example, the ordinary power lines which are today used for illumination purposes. When such a power line supplies direct current, the terminal 16 will be negative and the terminal 17 will be positive.

The washers 6 are composed of insulation, preferably of a material of very low dielectric constant. These washers are made as thin as possible in order to make the dielectric material as small as possible. This is an important factor inasmuch as the electric field used in pulling electrons emitted from the cathode through the passages between the washers into the outer region must pass between these washers. If the washers are thick and possess a high dielectric constant, they might act to shield the space between them from electric fields. This is especially true if the rings 7 are not intimately in contact with the washers 6. Thus it will be seen that such intimate contact, as well as the use of thin washers, are desirable in constructions of this kind. In addition to being thin, the washers should be spaced together as close as is practical in order to avoid any tendency for the discharge to localize.

I prefer to use a dielectric material for the washers 6 which has a large positive temperature coefficient. There are a number of common insulating materials of this kind, one of which, for example, is aluminum oxide. Due to the fact that the cathode 5 is heated, the inner regions of the washers are, throughout the operation, at a higher temperature than the outer portions. With the use of dielectric material of the foregoing nature, the inner regions will thus have a higher dielectric constant than the outer regions. This variation in dielectric constant will cause the electric field extending between the washers to be distributed as illustrated approximately in Fig. 3, in which the curved lines extending between the washers 6 represent lines of electrostatic force. It will be noted that these lines of force converge as they pass away from the cathode 5 toward the rings 7 which constitute the anode of the electrode system. The variation in dielectric constant of the washers 6 might be obtained in other ways, such as by making the inner portions of the washers 6 of a material having a higher dielectric constant than the outer portions thereof.

The arrangement as described above constitutes an effective and useful means for projecting electrons emitted from the cathode 5 into the gaseous medium external to the electrode assembly, without causing the cathode to be bombarded by high speed positive ions. If such bombardment of the cathode were permitted to occur, the cathode coating would be destroyed and the useful life of the lamp terminated. Likewise the arrangement described constitutes an efficient means for converting the kinetic energy of the electrons into light for illumination or other purposes. Due to the electrostatic field pattern described above, electrons emitted from the cathode 5 are projected outwardly by the field, and pass radially along the horizontal passages between adjacent washers 6 in a direction which tends to concentrate the electrons along the central portion of each such passage. This is due to the fact that the electrons are pulled toward the central region of each of these passages, and away from the surfaces of the washers. In this way the electrons have very little tendency to fall upon the washers, but are projected to substantially the full voltage impressed upon the lamp into the gaseous atmosphere surrounding the electrode assembly. Electrons that are deflected within the electrode assembly by atoms of the gas and which collide with the washers are either neutralized by positive ions or, in the case where the washers are made slightly conductive as will be described below, these electrons are conducted away to the anode structure. However, comparatively few electrons are thus lost on the washers. Positive ions which are created by the discharge and which tend to fall toward the cathode 5 will be directed along electrostatic lines of force, and will thus be pulled toward the washers and will in general fall upon one of these washers. However, such positive ions will seldom, if ever, be able to fall through the whole potential drop applied to the lamp. In this way high speed positive ions with energy sufficient to cause disintegration will seldom be found. In other words, before an ion receives sufficient acceleration to produce disintegration, it will be captured by one of the washers. Under these conditions, disintegration of the cathode as well as other parts of the electrode structure is practically nonexistent.

Distribution of the entire voltage of the ordinary power supply line along each passage between adjacent washers is produced because the system is so designed that the rate of loss of ions on the washers is potentially greater than the possible rate of production of ions by the electric discharge. This characteristic is made possible when the electrons in the regions between the washers move with an ionizing free path so long that the time between the ionizing collisions is long in comparison with the time needed for an ion to wander to a washer and be lost. I have found, for example, that if the distance d, as represented in Fig. 3 between adjacent washers, is less than about one millimeter, and if the pressure of the mercury vapor is about one micron, then the desired voltage distribution can be secured. In a particular embodiment, the spacing between adjacent washers could be about .010 inch. In general the total distance L from the cathode surface to the anode rings 7, as shown in Fig. 3, should be long in comparison to the distance d, and preferably L should be more than about three times d.

A desired dielectric material for the washer 6 may be a granular structure of silicon dioxide. The washer may first be made of glass having as one constituent silicon dioxide, and additional constituents which may be dissolved by reagents which are relatively inert with respect to silicon dioxide. Such a glass washer is then treated with such a reagent to dissolve the additional constituents, leaving substantially only silicon dioxide. Ceramic materials of various kinds also have a granular structure which make them desirable for such washers.

In order to minimize effects of negative charges collecting on the washers, it is preferable that the washers be slightly conductive. This can be accomplished by immersing the granular or porous washers described above in a solution of a metallic salt, such as ferric chloride or a nickel salt. The washers are dried and subjected to heat in a vacuum furnace or a hydrogen furnace. The salts contained within the pores of the washer are decomposed, liberating small particles of conducting material, which are thus dispersed throughout the porous insulator. By choice of a solution of proper concentration, the preferred degree of conductivity can be realized. Other methods of producing the desired conductivity may be used. For example, lamp black may be dispersed throughout a ceramic composition, which is then hardened in the usual manner by heating.

In some cases it is desirable to increase the porosity of the insulating washers to such an extent as to result in a lace-like structure for the washers, such as illustrated in Fig. 5, in which the washer material 6 is provided with pores 6a which are sufficiently large to constitute openings extending through the washer. One way in which a lacy washer of this kind may be made is to prepare a mixture of silicon dioxide and a component which may be dissolved by a reagent of the kind described above. Such a mixture is prepared, fused, and allowed to cool. The fused glass-like mass is then ground into a very fine powder. A second batch consisting substantially solely of the component to be dissolved out may be prepared, fused, and then ground into a coarse powder. This coarse powder may be passed through sieves so as to obtain a material having grains with a diameter of about .010 inch to .015 inch. The coarse and fine powders are then mixed, formed into washers, and heated to just about melting point of the constituent which is to be dissolved out. Thereupon said constituent is treated to the reagent so as to dissolve it, leaving the desired lace-like structure of silicon dioxide constituting the body of the washer.

The lacy washers of the above type are desirable since the total amount of dielectric therein is quite small. This gives the desirable effect of a low dielectric constant. Such washers also have the added property of affording passages from one inter-washer space into an adjacent inter-washer space, thus permitting ions from one region to wander into an adjacent region. This action tends to make all of the inter-washer regions share the current of the lamp substantially equally. The lacy and porous structure also minimizes short-circuiting phenomena that might be brought about by metallic deposits on the surfaces of the washers from any residual disintegration that might occur within the lamp.

All of the above washers have one thing in common, namely passages between them which are so small that the washers present sufficient surface for deionization to keep the volume ionization between them down to a value too low for complete neutralization of the electronic space charge. They give a tube a positive current voltage characteristic, and act as ion catchers to eliminate or substantially reduce disintegration.

Under proper conditions such as described above, the discharge has the desired rising or positive current voltage characteristic which enables the lamp to be connected directly to the usual power line without the use of stabilizing resistances or other impedances. The structure described above produces in effect an electron gun which makes substantially all of the electrons fall through the total voltage applied to the lamp, and causes the ions to fall through only a fraction of this voltage.

The electrons which leave the electrode assembly or electron gun plough into the surrounding region with speeds obtained by a fall through 110 volts more or less where the usual voltage lines are applied to the lamp. Each such electron may produce on the average a total of 2.7 ions before losing its powers of ionization. In the particular gas mixture, the radiation of the wave length of 2537 Angstrom units is excited in considerable strength. Also many photons of still shorter wave length are produced, that of 1840 Angstrom units being quite strong.

If the size of the envelope 1 is too small in diameter in comparison to electronic range or free path, then relatively high speed electrons will collide with the envelope walls and charge the walls to a considerable negative voltage. Such an action represents a loss in so far as the production of light is concerned. In order to obtain a high efficiency of conversion of electrical energy into light, several precautions should be observed. In the first place the electronic range should not be permitted to be great enough to reach the walls of the envelope. In order to accomplish this, the envelope is made relatively large and the electrode assembly or electron gun is placed substantially in the central region thereof. In this way an electron path longer than the free path is traversed by the electrons projected by the electron gun before reaching the envelope wall. Under these conditions substantially all of the energy of the electrons will be consumed in exciting the gaseous atmosphere so as to produce the desired light radiations. I have found that the addition of helium, as described above, helps to scatter the electrons and prevent their reaching the walls of the envelope. Helium to one or more times the pressure of the maximum value of the mercury vapor during operation is desirable.

Another aspect of this invention which increases the efficiency of the light production is that the total outside area of the electron gun is made as small as possible. This reduces the surface for loss of ions from the general gaseous region outside of the electron gun within the envelope 1. It also reduces the surface for loss of photons of 2537 and 1840 Angstrom unit wave lengths and other desired wave lengths whose radiation density is greatest in the interior portions of the lamp.

Another way in which the efficiency of the lamp may be increased is by using as the coating 14 a fluorescent material which is responsive to the 2537 Angstrom wave length and also to shorter wave lengths. A useful material responsive to wave lengths from about 1200 to 3100 Angstrom units is Mg_2WO_5 activated with small amounts of bismuth or equivalent materials.

Other electron gun arrangements incorporating my invention could likewise be used. For example, in Fig. 4 there is illustrated a double electron gun arrangement which may be substituted for the electron gun arrangement in Fig. 1 in instances where it is desired to utilize both halves of an alternating voltage in the production of light in the lamp. In Fig. 4 the same reference numerals are applied where the elements are identical with those discussed in connection with with the embodiment in Fig. 1. In the embodiment of Fig. 4 a pair of cathodes 18 and 19 are provided. These cathodes may be mounted in line with each other but separated and insulated from each other by means of a central insulating spacer 20. The cathodes 18 and 19 contain resistance heaters 21 and 22, respectively. These heaters are connected in series, and are so designed that they may thus be connected directly to the usual power supply line. One end of the series-connected filaments is connected to a conducting standard 23 sealed in the press 3 and provided with a lead-in conductor 23a so as to provide an external connection thereto. The other end of the serially-connected heaters is connected to a conducting standard 24 likewise sealed in the press 3 and provided with a lead-in conductor 24a. The cathodes 18 and 19 are surrounded by washers 6 and rings 7 as described in connection with Fig. 1. The rings 7 associated with the cathode 18 may be connected to conducting standards 25 and 26, while the rings 7 associated with the cathode 19 are connected to conducting standards 27 and 28. The standards 25 and 26 may be separated and insulated from the standards 27 and 28 by the central insulating spacer 20. The conductor 24 may be electrically connected to the standard 27 by means of a conductor 29, while the conductor 23 may be connected to the standard 26 by means of a conductor 30. In this way, when the lead-in conductors 23a and 24a are connected to a suitable power line, the anode structure of the cathode 18 is connected to one side of said line, while the anode structure associated with the cathode 19 is connected to the other side of said line. In order to impose proper potentials between the cathodes and their associated anode structures, the cathode 19 is connected by means of a conductor 31 to the standard 25, while the cathode 18 is connected by means of a conductor 32 to the standard 28.

When the electrode structure cf Fig. 4 is incorporated within a lamp structure such as described in connection with Fig. 1 and the leads 23a and 24a are connected to the usual power supply line, each half of the electrode structure will alternately act as an electron gun to project streams of electrons into the surrounding gaseous atmosphere as the respective anode sections become positive. In this way both halves of the alternating voltage applied to the lamp are utilized in the generation of light radiations.

Small constricted beams of electrons emitted from the electron guns of lamps of the foregoing type give rise to a very uniformly distributed fluorescent light. I believe that this is caused by two effects. One of these effects is that the electrons which are projected from the electron gun are scattered, and they in turn produce on the average of 2.7 positive ions and 2.7 electrons. The 2.7 electrons are scattered and wander around, losing energy in making more photons. Some of the photons combine in three body collisions, and give rise to more photons. The second of these effects is that a photon of resonant radiation is absorbed by a gas or vapor molecule, and reemitted in a random direction. In this way the photons are scattered uniformly throughout the bulb, producing the uniform distribution of light throughout the fluorescent coating.

Of course it is to be understood that this invention is not liimted to the particular details of construction, materials, or processes, as described above, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a cathode, an anode, and an interposed barrier structure, said barrier structure having closely spaced dielectric walls providing one or more electron passages extending from said cathode through said barrier structure to said anode and into said gaseous atmosphere, the portions of said dielectric walls adjacent said

cathode having a higher dielectric constant than the portions of said walls adjacent said anode.

2. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a cathode, an anode, and an interposed barrier structure, said barrier structure having closely spaced dielectric walls providing one or more electron passages extending from said cathode through said barrier structure to said anode and into said gaseous atmosphere, said walls being formed of a dielectric material having a substantial positive temperature coefficient.

3. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a thermionic cathode, a relatively cold anode, and an interposed barrier structure, said barrier structure having closely spaced dielectric walls providing one or more electron passages extending from said cathode through said barrier structure to said anode and into said gaseous atmosphere, said walls being formed of a dielectric material having a substantial positive temperature coefficient.

4. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a cathode, an anode, and an interposed barrier structure, said barrier structure having closely-spaced dielectric walls providing one or more electron passages extending from said cathode through said barrier structure to said anode and into said gaseous atmosphere, said anode being in intimate contact with the material of said barrier structure on the outside of said structure.

5. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a cathode, an anode, and an interposed barrier structure, said barrier structure having closely-spaced dielectric walls providing one or more electron passages extending from said cathode through said barrier structure to said anode and into said gaseous atmosphere, said walls having conducting material dispersed therein to render them slightly conductive.

6. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, said means comprising a cathode, an anode, and an interposed barrier structure, said barrier structure having closely spaced wall members providing a plurality of electron passages extending from said cathode through said barrier structure to said anode, said wall members being foraminous whereby small passages interconnecting said electron passages through said wall members

are provided, said passages being of sufficient size to permit the travel of ions therethrough.

7. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, a pair of means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, each of said means comprising a cathode, an anode, and an interposed barrier structure, means connecting the anode of one of said projecting means and the cathode of the other of said projecting means to a first conductor, means connecting the cathode of said one projecting means and the anode of said other projecting means to a second conductor, said barrier structures each having closely spaced dielectric walls providing one or more electron passages extending from each cathode through said barrier structure to the corresponding anode, the length of each of said electron passages being of the order of three times the width of said passage or greater.

8. An electrical gaseous discharge lamp comprising an envelope containing a gaseous atmosphere having a component adapted to generate light radiations, a pair of means for projecting a stream of electrons into said atmosphere to excite said component and cause it to emit light radiations, each of said means comprising a cathode, an anode, and an interposed barrier structure, means connecting the anode of one of said projecting means and the cathode of the other of said projecting means to a first conductor, means connecting the cathode of said one projecting means and the anode of said other projecting means to a second conductor, said barrier structures each having closely spaced dielectric walls providing one or more electron passages extending from each cathode through said barrier structure to the corresponding anode, the width of each of said passages being short in comparison with the ionizing mean free path of the electrons therein, the length of each of said electron passages being of the order of three times the width of said passage or greater.

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